Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin company, for the United States Department of Energy, under Contract DE-AC04-94AL85000. SAND98-1957

"If our nation and our precious freedoms are worth defending with the threat of annihilation, we are surely worth defending by defensive means that ensure our survival."

–President Reagan

"... America's unrivaled military superiority means that potential enemies that choose to attack us will be more likely to resort to terror instead of conventional military assault. Moreover, easier access to sophisticated technology means that the destructive power available to terrorists is greater than ever. Adversaries may thus be tempted to use unconventional tools, such as weapons of mass destruction, to target our cities and disrupt the operations of our government. They may try to attack our economy and critical infrastructure using advanced computer technology."

– Summary of Presidential Decision Directive 62, Combating Terrorism

What is Surety?

Surety is a level of confidence that a system will operate exactly as planned under both expected and unexpected circumstances.

Surety attributes:

Reliability in normal environments

Our critical national defense systems and infrastructures can operate without failures.

Safety of people and surroundings in abnormal environments

Our assets can better withstand natural disasters.

Security and Use Control in malevolent environments

Our forces can anticipate and mitigate attacks on Americans.

Palomares 1964

Thule 1968

The increased state of readiness throughout the early stages of the Cold War led to a number of aircraft crashes involving nuclear weapons. Early safety designs worked as intended. But analysis of these crashes reinforced the need for rigorous, systemic approaches to surety—reliability, safety, and security and use control. Developing these approaches and putting them into use in a fail-safe way has been a major part of Sandia National Laboratories' mission since our beginning. If the harnessing of nuclear energy was the technological achievement of the 20th Century, then the further development and maturity of surety—which has prevented accidental nuclear detonations—can be one of the technological triumphs of the 21st Century.

Surety Science and Engineering:
So That Things are Sure to Work

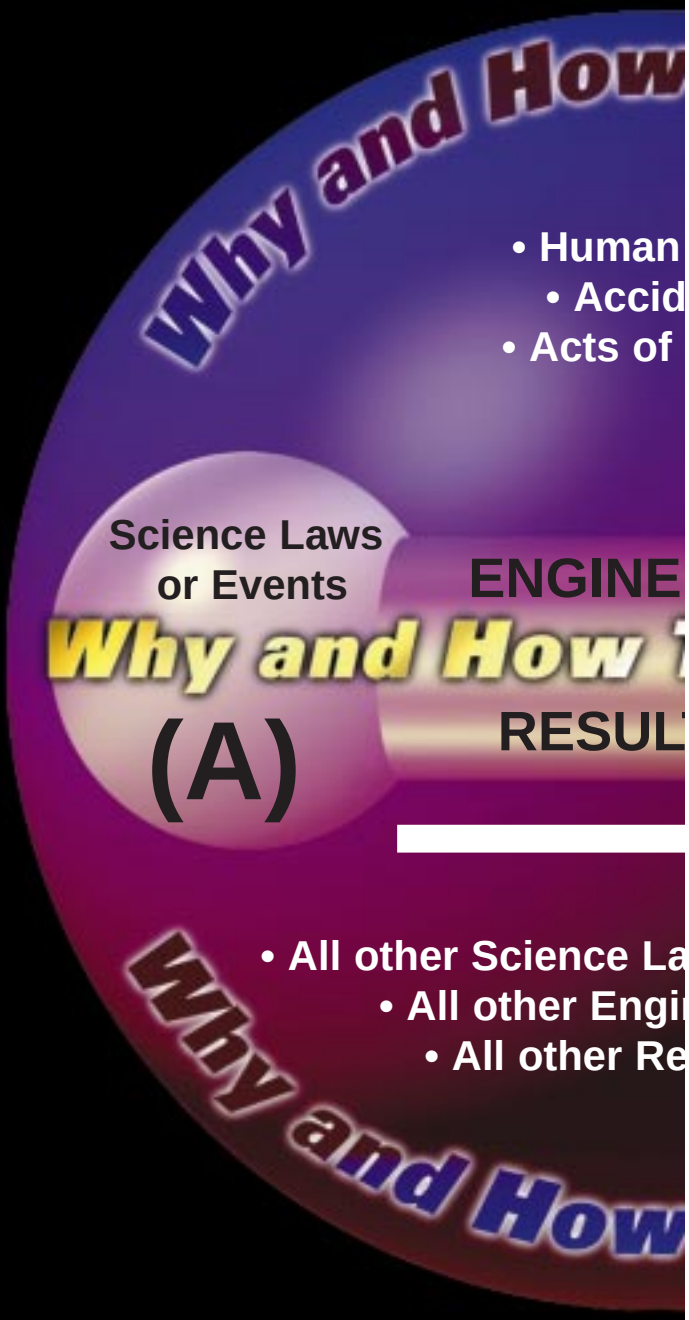
Until the advent of nuclear weapons and other high-consequence systems, we were satisfied to understand why and how things worked. We used science and engineering to turn matter and energy into structures, machines, and products useful to people.

We were satisfied that human ingenuity turned scientific knowledge and engineering processes "A" into useful innovations "B."

Beginning with the invention of nuclear weapons through the Manhattan Project, we entered a new era of high-consequence management. We built the first nuclear reactors and separation plants to produce plutonium and enrich uranium. We realized that there are a limited number of ways for a system to operate as intended, but there are many more ways for it to fail and produce unintended consequences, some of which can be catastrophic.

To prevent catastrophes, we had to go further and thoroughly understand why and how things fail, even if the failure mode was too unlikely to consider from a traditional engineering approach.

Thus was born *Surety Science and Engineering*.

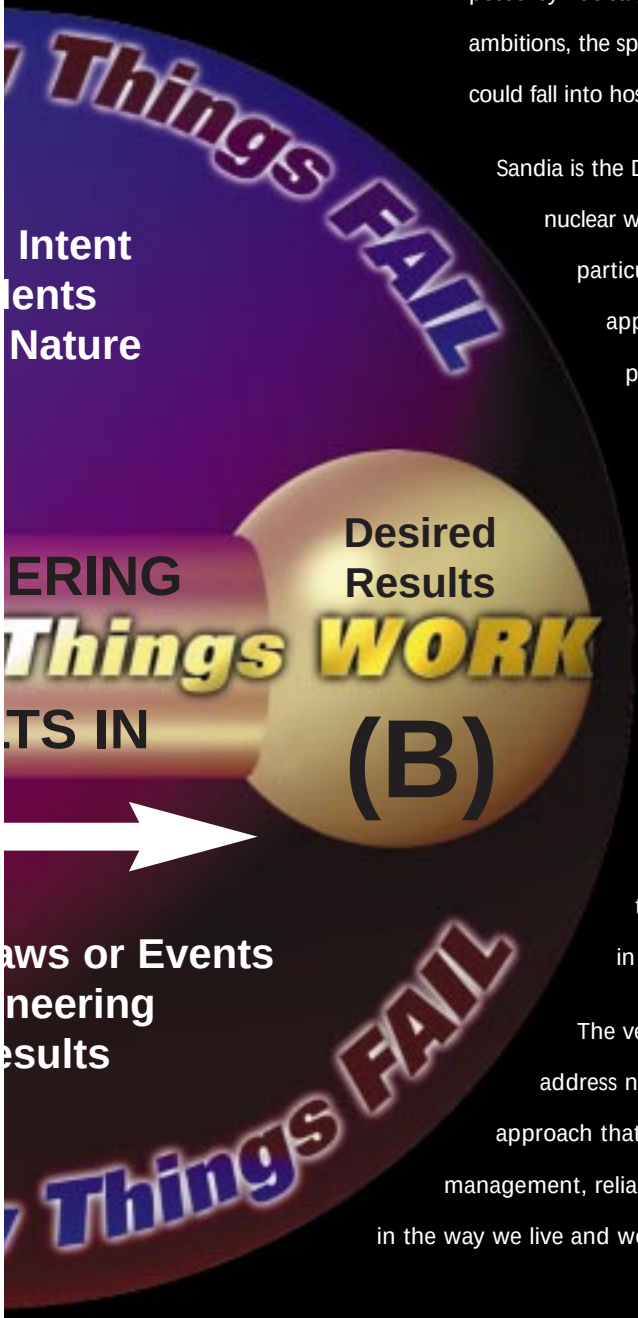


Our Increasingly Complex World Demands Surety

Sandia's surety culture is a result of its primary mission in national defense

Even though the two nuclear superpowers have agreed to shrink their arsenals, the threat posed by nuclear, chemical, and biological weapons remains. Regional instabilities, territorial ambitions, the spread of advanced military technologies, and the risk that nuclear materials could fall into hostile hands present a continued threat to the United States.

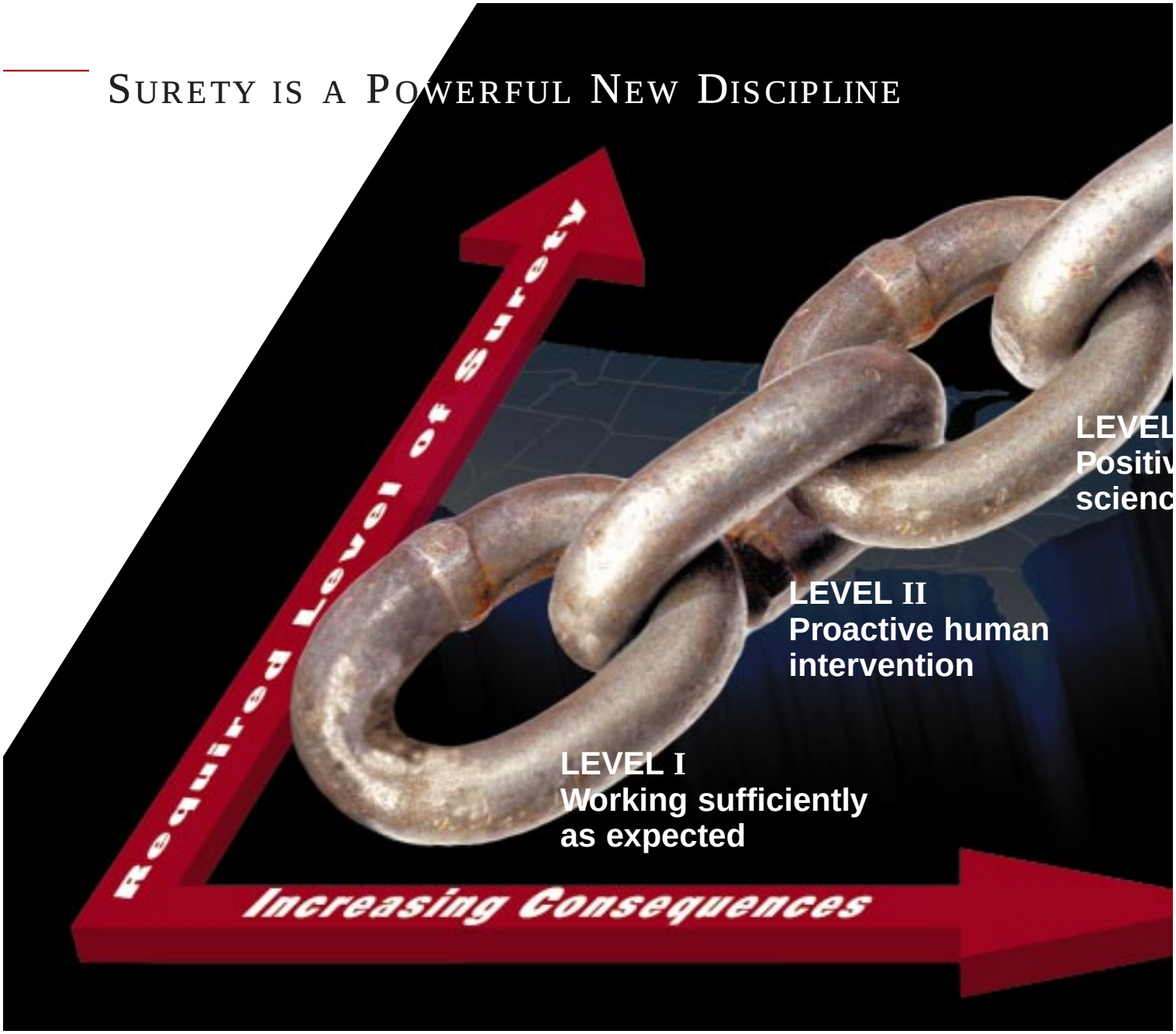
Sandia is the Department of Energy facility responsible for systems engineering of nuclear weapons and for system-level stewardship of the U.S. nuclear arsenal, with particular emphasis on surety. Sandia's 50-year history in developing and applying surety principles has provided the nation with a nuclear weapons program that has never experienced the unthinkable—an accidental nuclear detonation.



Many public and private institutions contribute to the surety of the nation. In many cases, partnerships manage system-level surety. For example, the Department of Defense is accountable for the surety of complete weapon systems and the DOE is responsible for the surety of the nuclear warheads. At the national laboratory level, Los Alamos and Lawrence Livermore national laboratories are accountable for the nuclear explosive. Sandia is accountable for the surety of the electronic, mechanical, and aerodynamic subsystems and the stockpile infrastructure. Surety science and engineering originated in Sandia's experiences with nuclear weapons and derivative applications.

The very same surety science and engineering principles are being used to address national problems in reliability, safety, and security. The same systemic approach that incorporates modeling and simulation, testing and evaluation, risk management, reliability development, and physical security can also safeguard Americans in the way we live and work, and as we move into the progressively complex future.

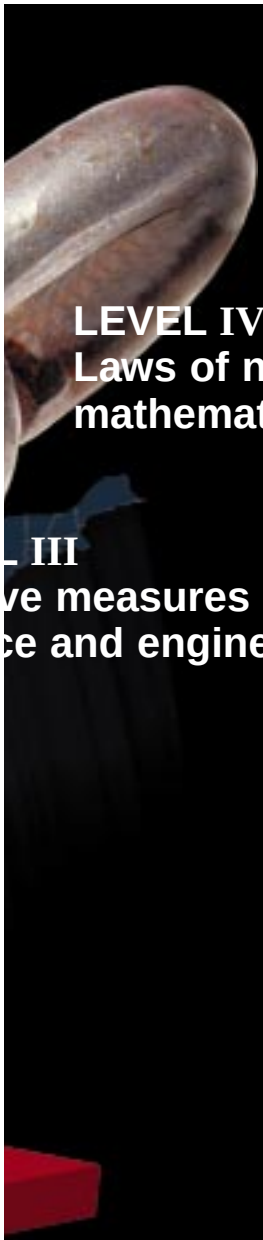
Surety is a Powerful New Discipline



Over the past 50 years, Sandia has studied and advanced solutions for the surety problems of a broad spectrum of national and international systems.

The benefits of surety are straightforward. But achieving surety relies on all the sciences—physical, chemical, and biological—as well as mathematics, engineering, and human and societal studies.

Sandia's rigorous, systemic approach defines four levels of surety. Higher-consequence risks require higher levels of surety.



LEVEL IV
Laws of nature and mathematics

L III
ve measures from ce and engineering

The *first level* of surety is adequate for most manufactured goods and predictable events in the everyday world. It relies on machines, humans, and systems working as expected. Warranties, insurance, or simple replacement are sufficient when things fail.

The *second level* relies on highly trained, proactive human intervention for higher-surety systems. Commercial air travel and most military operations belong in this second level. In these cases, well-trained professionals adapt to changing circumstances to provide surety.

However, the limited ability of people to interpret new experiences with old and inappropriate expectations can be disastrous. The *third level* uses positive measures from science and engineering to provide greater assurance that systems operate as planned or fail gracefully. The automated passive or active cooling systems in a nuclear reactor illustrate this level of surety, as do the surety systems built into older nuclear weapons.

The *fourth level* of surety uses—to the extent possible—only the laws of nature and mathematics to assure safety and reliability, preclude unintended consequences, and continually move toward the goal of absolute surety. Modern nuclear weapons use this level of surety. As the already old nuclear stockpile grows even older, this level of surety is continuously tested and refined at Sandia.

The four levels are only the beginning. Within each level, principles, approaches, and tactics guide designers. Sandia has systematized all these elements into a powerful new surety strategy that is akin to quality but surpasses it in breadth, depth, and scope.

Everyday surety—a systemic approach

The difference between systemic and systematic approaches is subtle, but essential to understanding the broad scope of surety.

Systematic—an attribute of the scientific method—implies a thorough, ordered approach to a problem or set of problems. A systematic approach is as broad as the scope of the problem(s)—it covers all the bases in a logical, defined sequence.

Systemic goes beyond systematic to encompass not just all the bases, but the entire ballpark, and the impact of the ballpark on the city beyond. Literally, systemic means “of the whole body”—whether that body is an engineered system or an international political effort toward nuclear nonproliferation.

Nuclear Weapons Surety Has Led to the Development of Numerous Technologies That Benefit Americans

Surety has already paid a substantial dividend

Surety is an evolving discipline. Like quality, it was first perceived to cost money. But we soon learned that quality avoided some previously hidden costs and quality was proclaimed to be free. Now we realize that quality pays. We will take the same path from "surety costs" to "surety pays."

What are the dividends of our nuclear weapons surety heritage? The Cold War was won without an accidental nuclear detonation anywhere. Now we are working with the former Soviet Union to make the world a safer place by increasing the surety of nuclear materials.

Many technological advances came directly from our weapons surety program. Nuclear weapons needs, for example, drove the control of particulate contamination in manufacturing. The result—clean rooms—enabled a $960 billion worldwide electronics industry and revolutionized surgery and pharmaceutical processes.

Detection and sensing technologies led to new medical instruments, crime-fighting systems, explosives detection for airports, airbags, and chemical and environmental analysis tools. Energy from radioisotopes has facilitated the exploration of our solar system and beyond.

A derivative of weapons parachute technology enabled better airbags for cars and an inexpensive, reliable landing system for Mars Pathfinder.

The Surety Advances of the Future Will Bring Competitive Advances To Our Nation

Sharing surety practices, technologies, and strategies will bring advances to our nation in many areas and help share the cost of providing more advances in surety. Our critical infrastructures will be more robust because surety showed us how to analyze complex, interconnected systems. The surety of weapons in our enduring stockpile will be continually enhanced to assure a credible, safe, and secure deterrent.

Modern approaches to understanding and managing nuclear weapons rely on advanced computer modeling and simulation to predict performance and assess the aging and deterioration of weapon components. These techniques are leading to revolutions in engineering and manufacturing. Modeling and simulation promise more cost-effective surety, better design-to-manufacture cycles, and better quality and competitiveness.

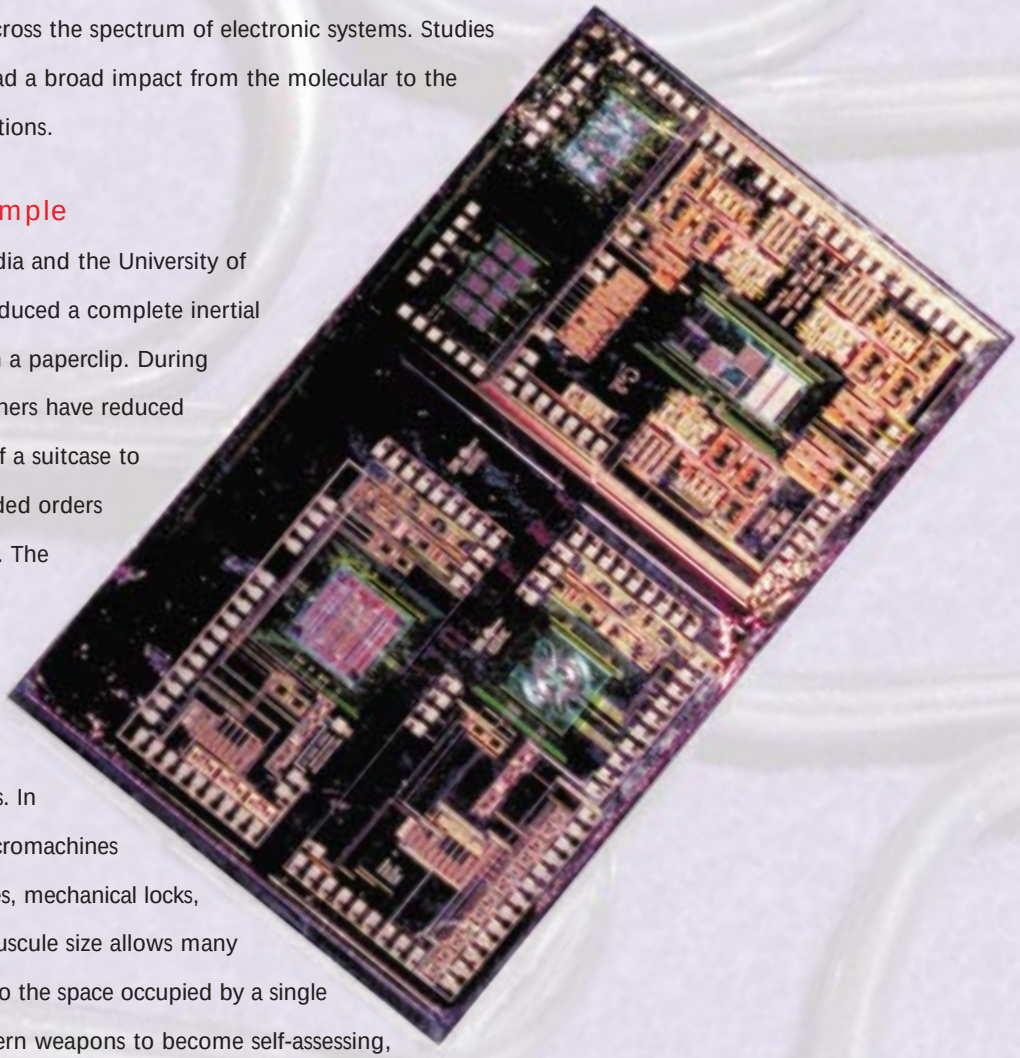
Application codes and problem-solving software enable industry to tackle previously insurmountable problems. Radiation-hardened electronics are essential to the communications satellites and space vehicles that have changed our everyday lives and our understanding of the universe. Our patented advances in locating failures in microelectronics are widely used throughout the industry to significantly reduce the time to fix yield, field, and design problems. They are also being used to assess the vulnerability of smart cards—credit cards that contain embedded chips. These partnerships enhance our ability to achieve significant savings by using the advances of the electronics industry in critical national security applications.

A new cost-effective forensic device originally developed to reveal tampering with nuclear materials can now reveal organic evidence at crime scenes.

Building in Surety

Sandia has continuously increased the level of surety in nuclear weapons. Modern safety systems rely, to the extent possible, only upon first principles of science to assure that the laws of nature must be violated before nuclear weapons safety is compromised. This is the highest level of surety.

The Accelerated Strategic Computing Initiative enables existing and new concepts and designs to be modeled and tested more exhaustively than ever before, leading a true revolution in engineering and manufacturing. The study of failure modes in commercial devices used in the weapons program has led to greatly improved reliability across the spectrum of electronic systems. Studies on aging of materials have had a broad impact from the molecular to the macroscopic in many applications.



A Modern Surety Example

A collaboration between Sandia and the University of California at Berkeley has produced a complete inertial guidance system smaller than a paperclip. During the last four decades, researchers have reduced these systems from the size of a suitcase to a soda can to a chip, and added orders of magnitude of functionality. The computer chips can be made thousands at a time at greatly reduced cost. They appear to be impervious to traditional countermeasures. In weapons, these intelligent micromachines can be used as optical switches, mechanical locks, and smart sensors. Their minuscule size allows many devices to be incorporated into the space occupied by a single older device and allows modern weapons to become self-assessing, which will reduce the costs of maintaining their safety, security, and reliability. These micromachines hold a larger promise—the second silicon revolution of integrated, intelligent, microelectronic, and micromechanical machines.

Fundamental Design Principles

Our surety approach has derived fundamental design principles to ensure surety. For nuclear weapons, these identify critical surety components and ensure they are isolated from the environment. We design these components to be fail-safe based upon fundamental laws of physics. They operate only upon receipt of signals that are not replicated in nature.

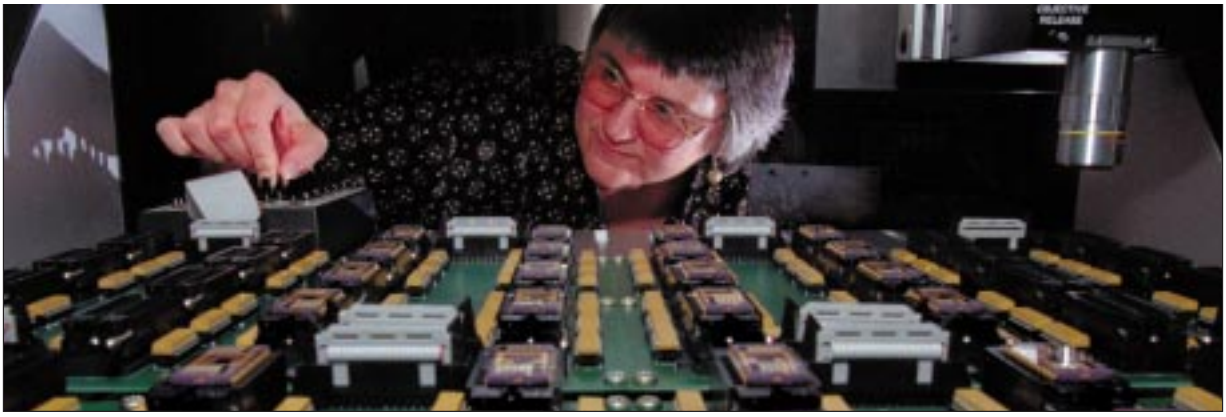
Materials Sciences

Because materials science is so important to a thorough understanding of weapons surety, Sandia has conducted the largest materials sciences research program within the national lab system. Improved materials and an understanding of how materials fail are critical to the surety of weapons. Many of these materials are now used in industry.

Independent Assessment

A culture of continual, independent assessment drives Sandia and our partners to remain vigilant to surety as our systems age, and to seek technological advancements that will improve surety. This culture is an essential element of maintaining the highest level of surety.

Sandia pioneered not only emergency management techniques, but also the planning and conduct of training exercises.



Condition Assessment

Condition assessment is an essential element of our role of providing reliability assessments for our nuclear weapons. Maintaining the surety of the enduring stockpile means creating new techniques and methods to assess the state of materials, components, and systems in normal, abnormal, and malevolent circumstances. Self-assessing weapons are possible today, and the same techniques could be applied to other high-consequence systems, such as aircraft.

Validated understanding is essential for surety. Quality measurements build confidence. In combination with the Accelerated Strategic Computing Initiative, experiments validate and improve the computer modeling and simulation codes on which our stockpile surety relies. Measuring events that create millions of degrees of heat in only billionths of a second is a challenge that Sandia has met time and again with unique capabilities in testing, surveillance, quality, and telemetry.

Emergency Management

No system can be completely safe and reliable forever. Understanding how things fail, planning responses, and then practicing the responses are essential to maintaining surety. To manage the first high-consequence system, the nuclear weapons program pioneered many of the principles and techniques of modern emergency management. The program developed concepts such as coordinated emergency operations, comprehensive information collection and management, risk and consequence analysis, accurate and pertinent decision support systems, ways to alert and inform the public, and how to plan and conduct training exercises.

Fifty Years of Surety Experience Provides the Foundation for Protecting our Critical Infrastructures

Nuclear weapons surety involves many complex and interdependent infrastructures—including making sure that nuclear materials production is safe, transporting weapons, managing and guarding nuclear facilities, assessing vulnerabilities of communications and control networks, and training response teams. The surety of these systems serves as a foundation for protecting all of our nation's infrastructures.

The infrastructure of the United States is a complex system of interconnected elements whose continued operation is vital to the security and well-being of the country.

Infrastructures are:

Power systems, oil and gas pipelines, water supplies, air traffic control, banking and financial services, telephone systems, computer networks, bridges, buildings, highways and railways, waterways, mass transit, and police, fire, and medical services.

Fifteen years ago, these infrastructures—which are generally operated by the private sector and regulated by government—were separate and distinct. Now, many are linked together or controlled by vast computer networks, increasing our productivity, but also making us much more vulnerable to disruption.

There is no question that our infrastructures are more vulnerable than ever. The President's Commission on Critical Infrastructure Protection reported that the capability to do harm, particularly through information networks, is real; it is growing at an alarming rate; and we have little defense against it. "Today, the right command sent over a network to a power generating station's control computer could be just as effective as a backpack full of explosives, and the perpetrator would be harder to identify and apprehend," the Commission stated.

That damaging command, or others like it sent to a communications, banking, transportation, or emergency response network, could cause a cascade of failures, crippling the economy of a region or the entire nation and weakening our national security. It could be done with a personal computer connected to the Internet. It could happen by mistake.

Or, as in the case of the massive power outage in the city of Auckland, New Zealand, it could result from the cascading failure of poorly maintained power cables.

Could it happen elsewhere? It already has!

- In August 1996, power cables in the Northwest sagged into tree limbs and plunged most of the West, from Canada to Mexico and from California to Nebraska, into darkness for several hours. When power was restored, some telecommunications systems were only two hours from exhausting their reserve power supplies and shutting down.
- In January 1998, a devastating ice storm in the Northeast left much of New York, New England, and southern Quebec without power, in some cases for more than three weeks. The losses for Canada alone were $1.6 billion.
- In May 1998, a single failed communications satellite disabled 90 percent of the pagers in our country, as well as ATMs, credit card systems, and TV and radio networks throughout the world. This failure affected physicians, law enforcement officials, and many others dependent upon instant communications.

Cascading failures due to accidents, mistakes, events of nature, or attacks are a near and present danger.

Surety Solutions for Protecting our Nation's Infrastructures

"Waiting for disaster is a dangerous strategy. Now is the time to act to protect our future."
—President's Commission on Critical Infrastructure Protection

Sandia's significant capabilities to protect the nation's infrastructure have been developed by our historical mission to protect the nuclear stockpile. The nuclear weapons program shows that complex, high-consequence systems do not have to fail. Modeling interdependencies, analyzing the consequences of thousands of scenarios, finding the indications and warning signs of impending failures, producing roadmaps to design and build systems with built-in surety, using Vital Issues Processes, information surety, highly secure supervisory control and data acquisition systems—these are all surety approaches developed over the past 50 years.

Modeling of Interdependencies

The interdependencies among infrastructures create vulnerabilities that are different and potentially more damaging than those of individual infrastructures. We need to understand and manage these interdependencies to minimize the impact of deliberate disruptions, human error, system complexity, or natural disasters. Although there are many individual infrastructure models, there are no models of the complex interdependencies.

At Sandia we are developing computer simulation tools that can predict and analyze the response of our critical infrastructures to unexpected perturbations. These simulations, coupled with Sandia's large-scale computing resources, identify the requirements for subsequent responses, remediation, and prevention. These capabilities could assist in the development of a national indications and warning system.

Indications and Warning System

The Defense Science Board has stated that an adversary could mount a structured attack against the U.S. infrastructure disguised as a series of unstructured, random events that appear to be the uncoordinated work of hackers.

There is no capability within the U.S. for an indications and warning system for attacks against the U.S. infrastructure. Sandia has developed many pattern recognition techniques for real-time target detection using ground, air, and space platforms. These techniques, along with new microsimulation models, provide unique capabilities against cyber attacks.

Furthermore, Sandia manages several international programs in nonproliferation and cooperative monitoring where secure data sharing is required. These DOE-funded programs provide another technical basis for designing an indication and warning system for the U.S. infrastructure.

Consequence Based Analysis

Definition of specific, quantifiable threats to the U.S. infrastructure has been elusive. This has made it difficult to identify critical nodes and design protective measures and has limited industry's participation and investment.

Consequence Based Analysis, developed by Sandia, identifies consequences to be avoided along with the cost of protection options. It identifies critical nodes, fundamental causes of failures, threat scenarios, and specific failure modes. These results may be extended through economic modeling to prioritize protection options, help identify roles and responsibilities, and assist with investment decisions.

Roadmapping

Roadmaps are strategic plans to develop and introduce technologies and policies that will maximize the benefits of a system.

Sandia has coordinated the efforts of stakeholders to create strategies for the protection of vulnerable infrastructure assets. A master U.S. Infrastructure Assurance Strategic Roadmap integrates six infrastructure areas: electric power, state and local emergency services, finance and banking, telecommunications, oil and gas, and transportation.

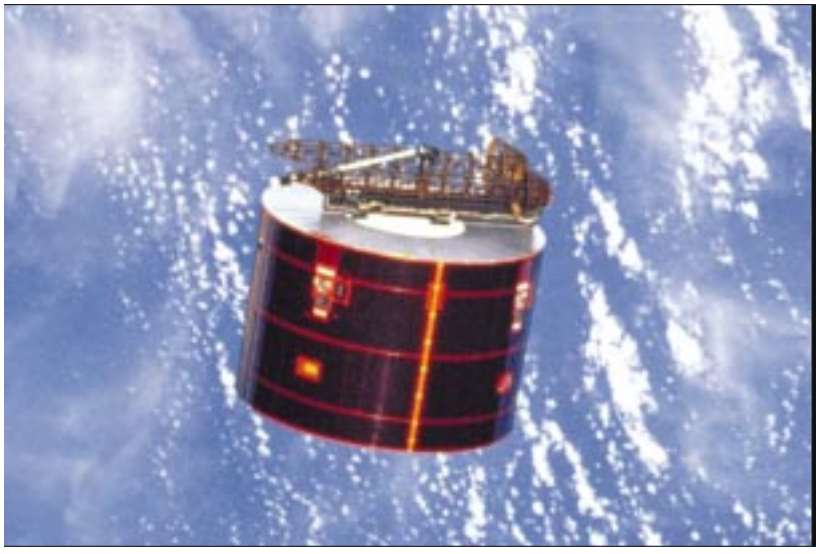
Vital Issues Panels

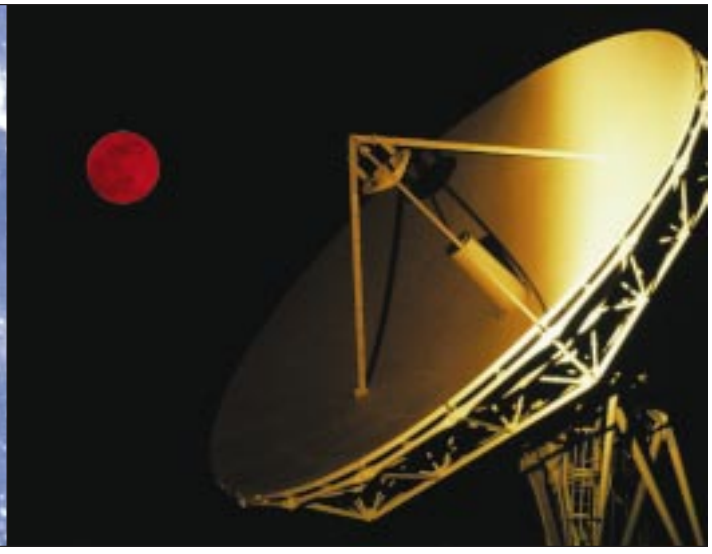
Prompted by U.S. recognition of its connection to the global environment and by concern about the impact on U.S. security of the failure of critical infrastructures, Sandia has begun efforts to provide solutions to decision makers throughout the world to help in the management of indigenous and transnational infrastructure issues that are critical to U.S. national security. The first step in these efforts has been the convening of several Vital Issues Panels to ascertain needs and requirements from in-country stakeholders. The Vital Issues Panels and other discussions have ascertained that there is a need for timely, worldwide access to relevant information, expertise, and technology related to infrastructure management.

Information Surety

All major elements of the U.S. infrastructure are critically dependent on information technology. This reliance creates new vulnerabilities that can be exploited by an adversary at low cost, remotely, and with deniability.

Beginning with use control of nuclear weapons, Sandia has a long history of developing information systems that have a high degree of surety. Our surety experience applies directly to other modern information systems. In information surety under abnormal circumstances, integrity includes both accuracy and authenticity and is a more appropriate descriptor than safety. Similarly, privacy denotes the information security concerns of industry, government, and individuals. Finally, use control translates to availability of information. Thus, information surety is the balancing of integrity, privacy, and availability of information.





High Surety SCADA Systems

Supervisory Control and Data Acquisition (SCADA) systems provide remote monitoring and control of critical infrastructures such as electric power, gas and oil, water, and others. Disruption of a SCADA network can lead to the destabilization of the underlying infrastructure as well as connected and neighboring infrastructures. Both cyber and physical threats are real and growing concerns. Sandia is developing High Surety SCADA systems that:

- Report the infrastructure state with confidence
- Measure the entire infrastructure
- Are robust in their communication and timely and optimal in their control
- Are confident in the accurate delivery of that control
- Provide these services under adverse conditions

Risk Assessment and Management, Safety of Nuclear Reactors, and Aging Systems

Sandia's "bang-and-splat" era—smashing a jet fighter into a concrete barrier or a 120-ton locomotive into a truck carrying a container meant for hazardous waste—was spectacular. These tests provided the data to verify the predictions of computer programs in use today.

Sandia's development of risk management techniques began decades ago during safety studies for nuclear weapons. We extended those techniques greatly when we developed methods for probabilistic risk assessment and applied them to studies of nuclear reactor safety.

We combine studies of component and system reliability, human reliability, and uncertainty analyses to perform integrated risk assessments.

We tested containment structural integrity, severe accidents, seismic reliability, missile impacts on structures, equipment operability, fire protection, and safeguards and security—all to thoroughly understand how things fail.

Today we are assessing the 20-year life extension of reactors, upgrading the instrumentation and control to increase reliability and reduce maintenance costs, and finding better ways to reduce the effects of aging. We also support DOE in improving the safety of its nuclear facilities and work with a number of foreign countries in areas such as computer code development, experimental work related to nuclear reactor safety, and consequence assessments.

Robotic expertise originated in part to handle nuclear waste.

Nuclear Waste

For more than 20 years, Sandia has played a key role in managing the nation's radioactive waste, including packaging and transportation. Now Sandia also applies expertise in computer analyses and modeling, in laboratory and field testing, and in the analysis and integration of extremely complex systems.

Making Aging Aircraft Safer

Our civilian airliners are remaining in service longer than originally envisioned. This life extension increases the importance of technologies for inspection and repair to keep the highest level of safety. Sandia's expertise in the areas of materials sciences, stewardship of an aging weapons stockpile, and extending the life of nuclear reactors directly applies to the problems of aging aircraft. Improved testing techniques such as ultrasound, eddy current, and thermal imaging can spot defects faster, earlier, and more reliably. New materials, such as bonded composite doublers, make aircraft repairs faster and sturdier.

Aging Cables

Because of the need to predict the long-term reliability of polymers in weapons, Sandia has developed expertise in the effects of radiation on the aging of cables, a subject that is of intense interest to the nuclear power community. This expertise is being applied to test cables in aircraft without physically removing them.

Physical Security and Surety Through Fighting Crime and...

Sandia is the DOE's lead laboratory for physical security. In the early 1970s, the DOE directed Sandia to address the potential theft of nuclear materials being transported between DOE facilities. We developed technical capabilities in security modeling and systems analysis, security equipment and components, and security systems engineering, integration, and implementation. We provide innovative and cost-effective solutions that protect nuclear and other vital assets and have adapted our techniques with federal agencies to enhance the security of our citizens and mitigate crime, fraud, and theft. Our strategies are to:

- Understand, develop, and predict the threat spectrum of the adversary
- Determine the consequence of an adversarial act and develop a spectrum of scenarios and responses
- Model facilities, security systems, and other factors
- Evaluate security systems through an assortment of tools
- Simulate environments and conditions so that many situations can be addressed without having to perform actual tests

...Making our Schools Safe

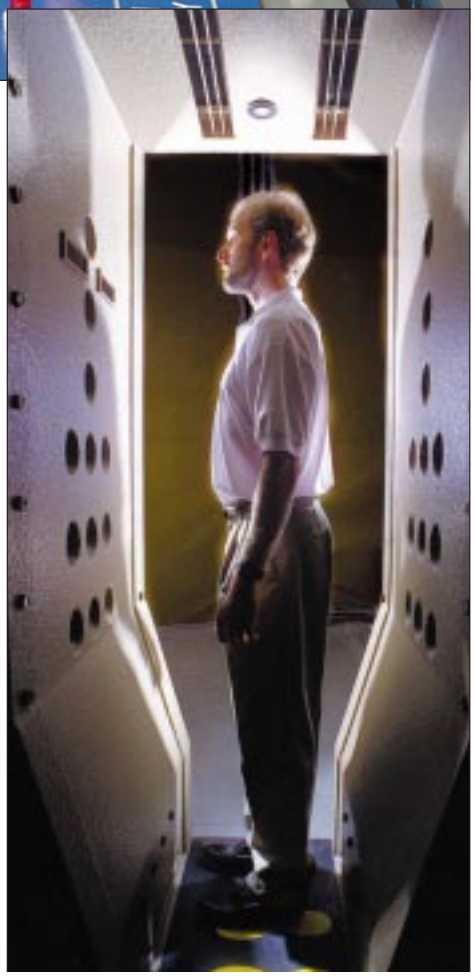
Everyday surety—safer schools

Sandia and Belen High School in New Mexico have partnered in school surety and have demonstrated impressive declines in violence, theft, and drug and alcohol use. The school reported a 90-percent decrease in vandalism and theft, 75 percent fewer fights on campus, and 95 percent fewer false fire alarms, among other improvements. Sandia now heads a new national center of expertise for school-security technologies and approaches.

Countering Crime and Terrorism

Many of the technologies that Sandia has developed for its physical security role are helping police departments and law enforcement agencies combat crime and terrorism. The National Institute of Justice has designated Sandia a satellite facility to act as liaison with local government. Among these developments are:

A "smart" gun will fire only in the hand of its owner.



An explosives detection portal detects infinitesimal amounts of explosives residues. Developed by Sandia for the Federal Aviation Administration for airport use, it is a descendant of the explosives detection technology developed to protect DOE facilities.

A technology for disabling bombs without setting them off is being used by an increasing number of police departments and emergency responders.

Snaring the Unabomber

When authorities captured the Unabomber, they discovered a completed mail bomb in his cabin. Sandians Chris Cherry and Rod Owenby not only disabled the bomb, but dismantled it intact, for use as evidence.

"I would like to recognize two New Mexicans who work at the Sandia National Laboratories in Albuquerque who have not been properly recognized. Chris Cherry and Rod Owenby ... at considerable risk to themselves, helped to lead to the capture and conviction of Theodore Kaczynski and put an end to his deadly attacks."
—President Clinton

When Things Fail—Investigating Tragedies

Sandia's surety expertise is often called upon to discover why and how tragedies occurred, such as the 1989 turret blast on the battleship Iowa and the 1996 explosion of TWA Flight 800.

Sandia scientists applied their materials characterization and explosives expertise in the reinvestigation of the USS Iowa explosion and determined that there were other probable explanations for the evidence and for the cause of the explosion. Similarly, Sandia's expertise in reconstructing complex system events led to potential ignition sources in the center wing tank of TWA Flight 800.

Making Buildings Safer and More Secure

In the Architectural Surety[SM] program, Sandia's surety expertise is making a contribution to structural reliability, safety, and security. Computer simulations and the testing of materials and scale models help predict the effects of natural disasters, weathering, aging, and explosions on physical structures and their mechanical components and systems. This capability provides a basis for managing risk and making design improvements, such as eliminating single points of failure, increasing structural strength, and using window glazing treatments that minimize injury to occupants.

A graduate Architectural Surety course has been taught in conjunction with the University of New Mexico's Civil Engineering Department, and other universities are developing partnerships with Sandia to offer courses in Architectural Surety.

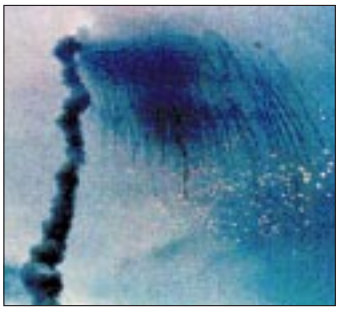
Air Transportation Oversight System

Surety principles are making the safest air transportation system in the world even safer. The Flight Standards Service of the FAA has embraced surety principles as the basis of the next-generation Air Transportation Oversight System. Surety principles, including improved data quality and appropriate information management, offer enhanced aviation safety for the American public.

Surety in Software and Hardware

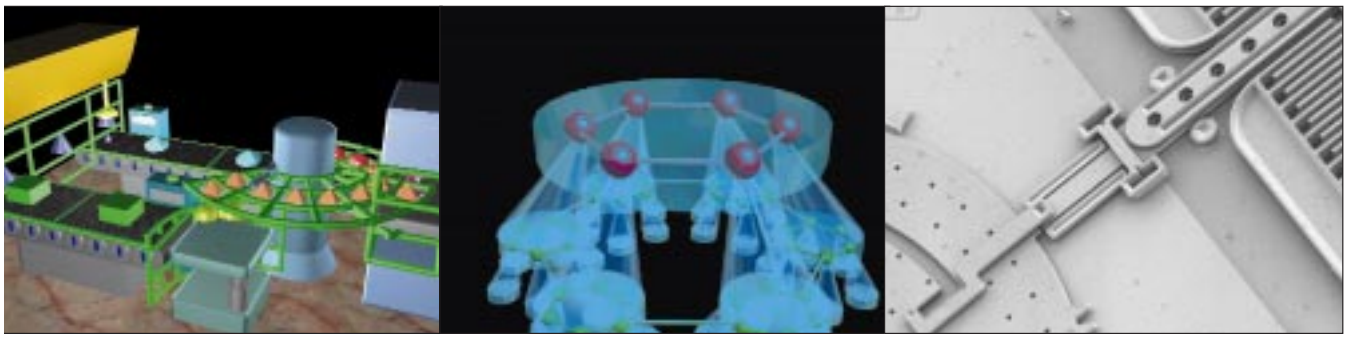
Every decade, the size and complexity of our software systems increase by an order of magnitude. But our ability to certify that these systems will function correctly under all conditions badly trails this growth. The traditional approach of coding, testing, and fixing is simply not acceptable. Consequently, software is not used in any safety-critical aspect of weapons. Because high-integrity software will be very valuable in the stewardship of the future stockpile, Sandia is conducting research on how to improve the way people build software.

Specifically, Sandia is researching knowledge capture, formal methods for creating correct-by-design software, and self-adaptive methods for high-integrity software.



An overlooked (and ultimately unnecessary) line of software did not account for the increased thrust of a more powerful engine and caused the failure of the first Ariane 5—at a loss of hundreds of millions of dollars.

"The cold, digital domain of silicon-based technology is drawing inspiration from an unlikely source: the living, breathing realm of nature."
—Wall Street Journal, January 16, 1996



High Integrity Software

(Left) Improved specifications (knowledge capture) through visualization of functional concepts—Specify the RIGHT THING

(Mid) Automated system creation that is verifiably correct based on precise mathematical methods—Construct the THING RIGHT

(Right) Systems Immunology™: methods for real-time fault detection and management—The THING may fail, so predict, anticipate, and adapt

Surety at the Bay Area Rapid Transit System

With Sandia's help, weapons surety principles in the areas of command, control, and use control are being applied for:

- ***Improving capacity and service***
- ***Reducing maximum power capacity***
- ***A dramatic increase in safety***
- ***Noise suppression***

Reliability and Vulnerability of Electronics and Microsystems

Revolutionary advances in electronics technologies require corresponding revolutionary advances in reliability technologies. Sandia is working to move from testing and screening-in reliability to building-in reliability. Sandia has a four-part program in science-based reliability engineering:

- Identify the failure modes
- Determine predictive models of the failure modes
- Develop model-based reliability engineering tools
- Implement new reliability paradigms

A single microscopic defect among the tens of millions of microscopic transistors and wires can cause a device to fail. This is the ultimate needle-in-a-haystack problem. Sandia has developed a suite of patented techniques that dramatically reduce the time to locate failures in complex microdevices. This has led to reductions in the time it takes to resolve problems that arise in design, manufacturing, or field use of devices.

Microdevices are vulnerable to malevolent attack. Sandia has an active program to assess the vulnerability of electronic devices and to devise methods to mitigate the effects of attacks.

In conjunction with the University of New Mexico, Sandia offers nationally televised, graduate-level courses in electronics reliability, failure analysis, and testing.

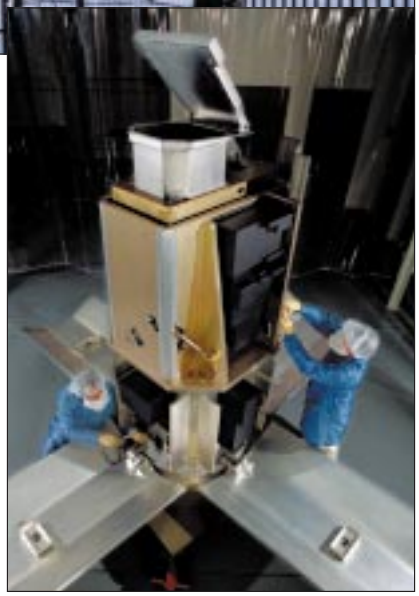
Nuclear Materials Management

In an era in which the United States and Russia each have declared a surplus of 50 tons of weapons-grade plutonium, it is frightening to realize that a small amount of this material could be used to fuel a nuclear detonation or cause widespread radioactive contamination.

Effectively managing the world's nuclear materials is a complex task. These materials exist in a variety of forms from irradiated reactor fuel to weapons-grade material. The materials are used for both military and non-military purposes in all regions of the globe and, between production and disposition, can follow widely diverse paths. The system for managing these materials must keep them safe and secure and must assure that they are used appropriately at all points along their varied paths, protecting them from theft or diversion and, where appropriate, providing for transparency and international accountability.

Working in conjunction with partners from government agencies, peers from other laboratories, and their counterparts in other countries, Sandia scientists and engineers have improved the protection of nuclear materials worldwide and have developed systems to facilitate increased international scrutiny. The security and material accountability at more than 50 nuclear material sites in the former Soviet Union (FSU) have been upgraded. In addition, the relationships we have built with FSU scientists have provided the basis for development of commercial opportunities for former weapons scientists and engineers in the FSU. As a direct consequence, Sandia's activities are helping to integrate the FSU technical infrastructure into the worldwide scientific and industrial community.

The Remote Monitoring System developed at Sandia simultaneously keeps tabs on nuclear depots at Russia's Kurchatov Institute and Argonne National Laboratory West in Idaho. The system combines photographic surveillance, intrusion alarms, motion detectors, and protective seals that are easily checked on a computer network.



Sandia has been designing and building instruments for satellites since the early 1960s. The latest is an R&D satellite to demonstrate and evaluate advanced multi-spectral and thermal imaging for nonproliferation applications.

Representatives of 30 countries get a close-up look at technologies used to protect stored nuclear materials. Examples are microwave sensors, cameras, and protective barriers.

Partnerships Will Provide Surety Solutions to the Challenges and Threats of the 21st Century

Sandia's surety strategy is transcending its Cold War origins through partnerships with other federal agencies, the Department of Energy, private industry, and universities to help manage the new 21st Century challenges with a new level of confidence.

- Safe, secure, and reliable energy
- Reliable infrastructures
- Managing the increasing complexity of interdependent systems
- Countering
  - physical and cyber terrorism
  - chemical or biological weapons
  - crime
- Safe and secure schools
- Solutions for
  - aviation safety and security
  - aging infrastructure
  - an aging nuclear stockpile
- Economic advantage to public missions from leveraging surety solutions from American industry
- No accidental nuclear detonations
- A credible deterrent

"Because so many key components of our society are operated by the private sector, we must create a genuine public-private partnership to protect America in the 21st Century."
—President Clinton

SURETY SCIENCE & ENGINEERING